

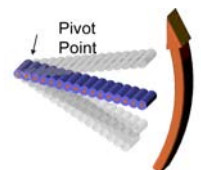
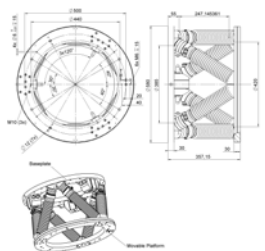
MS 155E User Manual**M-850K086 / M-850K109 Hexapod****6-Axis Positioning System**

Release: 2.0.0 Date: 2006-02-08



This document describes the following product:

- M-850K086
Hexapod Positioning System, Z-axis travel range ± 5 mm
- M-850K109
Hexapod Positioning System, Z-axis travel range ± 25 mm



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About this Document

Users of this Manual

This manual is designed to help the reader to install and operate the M-850K086 / M-850K109 Hexapod 6-Axis Positioning System. It assumes that the reader has a fundamental understanding of basic servo systems, as well as motion control concepts and applicable safety procedures.

The manual describes the physical specifications and dimensions of the M-850K086 / M-850K109 Hexapod 6-Axis Positioning System as well as the installation procedures which are required to put the associated motion system into operation.

Conventions

The notes and symbols used in this manual have the following meanings:



CAUTION

Calls attention to a procedure, practice, or condition which, if not correctly performed or adhered to, could result in damage to equipment.

NOTE

Provides additional information or application hints.

Related Documents

The software tools, which are delivered with the M-850K086 / M-850K109 Hexapod 6-Axis Positioning System, are described in their own manuals.

Updated releases are available via FTP or email: contact your Physik Instrumente sales engineer or write info@pi.ws.

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1 Introduction

NOTE

M-850K086 and M-850K109 differ from the standard M-850 Hexapod only in the mechanics part and the cabling. Any references to the M-850 in documentation and software should be taken as applying to the M-850K086 / M-850K109 Hexapods.

M-850K086 and M-850K109 differ from each other only in the travel range and in the length of the connecting cables.

The Hexapod mechanics provides servo-controlled motion in 3 translation axes and 3 rotational axes. The Z-axis travel range is up to ± 5 mm for the M-850K086 and up to ± 25 mm for the M-850K109 (depending on the positions of the other axis, see Technical Data, p. 59 for detailed specifications). Repeatability for a six-axis move is ± 1 μ m in Z, ± 2 μ m in X and Y, and ± 10 μ rad for rotations. The load capacity in case of horizontal mount is 2000 N in Z-direction. Optionally the Hexapod mechanics can be adapted for protection class IP 64 (see p. 13 for details).

The M-850K086 Hexapod includes:

- M850B0101 Hexapod mechanics
- M850B0114 cable set for Hexapod, consisting of
 - 1 x F-206.033 68-pol. 3 m,
 - 1 x K040B0057 MDR68/MDR68 1:1 21 m,
 - 1 x K060B0019 Switchcraft 4-pol. 21 m,
 - 1 x K060B0025 DSub 3W3 1:1 21 m,
 - 3 x K060B0028 Lemo/Lemo 2-pol. 6 m,
 - 1 x K040B0068 MDR68/3 x DB25 5.5 m with splitter box,
 - 3 x K040B0070 DB25f/DB25m 1:1 0.5 m,
 - 1 x C030B0003 Hexapod line driver box, controller side,
 - 1 x C030B0004 Hexapod line driver box, mechanics side
 - 1 x M850B0123 splitter box
- M-850.502 M-850 Hexapod motor controller
- M-890.HS software CD for M-850 und M-840
- 3763 line cord
- 4296 US keyboard
- F-206.MC6 manual pad with interface board

- 000013094 screw set for mounting
- 000012852, 000012853 O-ring seals for protection class IP 64
- MS 155 User Manual (this document)

The M-850K0109 Hexapod includes:

- M850B0111 Hexapod mechanics
- M850B0115 cable set for Hexapod, consisting of
 - 1 x F-206.033 68-pol. 3 m,
 - 1 x K040B0071 MDR68/MDR68 1:1 35 m,
 - 1 x K060B0026 Switchcraft 4-pol. 35 m,
 - 1 x K060B0024 DSub 3W3 1:1 35 m,
 - 3 x K060B0027 Lemo/Lemo 2-pol. 10 m,
 - 1 x K040B0069 MDR68/3 x DB25 10 m with splitter box,
 - 3 x K040B0070 DB25f/DB25m 1:1 0.5 m,
 - 1 x C030B0003 Hexapod line driver box, controller side,
 - 1 x C030B0004 Hexapod line driver box, mechanics side
 - 1 x M850B0123 splitter box
- M-850.502 M-850 Hexapod motor controller
- M-890.HS software CD for M-850 und M-840
- 3763 line cord
- 4296 US keyboard
- F-206.MC6 manual pad with interface board
- 000013094 screw set for mounting
- 000012852, 000012853 O-ring seals for protection class IP 64
- MS 155 User Manual (this document)

1.1 Safety Precautions



CAUTION

Do not hold the Hexapod on the struts!

CAUTION

Do not interchange the C030B0003 and C030B0004 line driver boxes when connecting the system. Strictly adhere to the connecting instructions given in this documentation and any accompanying Technical Notes and to the labeling of the boxes and cables.

Incorrect connecting can cause damage to the equipment.



CAUTION

Scan command runout may cause damage to the attached application.

The trajectory specified by the [X] [Y] [Z] [U] [V] and [W] parameters to the FSC and FSN scan commands is not followed as exactly as motion initiated with a MOV command, but rather with a certain amount of wobble. For large scanning ranges, for example 1 mm, this may result in an additional deviation of up to 2.6 μm from the desired trajectory, which, if unexpected, could damage the attached setup.



CAUTION

Note that with the servo-control loop OFF, set with the **SVO** command, the hexapod position is fixed by friction only. As a consequence of this, load capacity may sink dramatically. Hexapods can get damaged and sink down in this case.



1.2 Software Overview

NOTE

Any references to the M-8x0 or F-206 in documentation or software should be taken as applying to the M-850K086 / M-850K109 Hexapods.

This manual contains a listing of the commands which are used with the Hexapod Controller. It supersedes the standard M-840/M-850 User Manual MS 54E which is on the software CD.

A detailed description of the software to be run on your host PC is to be found in separate manuals which are included on the M-840/M-850 software CD. The following documentation provided on this CD is relevant for the M-850K086 / M-850K109 Hexapods:

- Hexapod Control software (GUI for Microsoft® Windows platforms)
- LabVIEW drivers (support the PI General Command Set based on ASCII communication)
- Hexapod DLL (Windows DLL Library)
- COM module (for Microsoft™ Windows platforms with COM support installed)

2 Quick Start

CAUTION

Never hold the Hexapod on the struts!

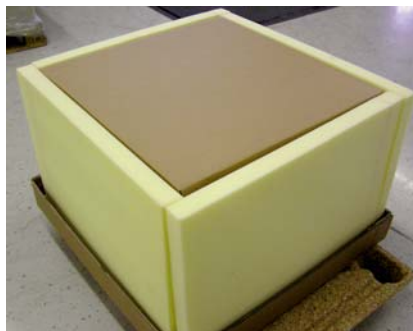
!

2.1 Unpacking

The Hexapod mechanics and the controller are each shipped in separate, special cardboard boxes with form-fit styrofoam inserts. The size and elasticity of the packaging has been calculated to prevent damage to the equipment during shipping. It is important to preserve these materials in case you ever need to return the units to PI for servicing.

The figures below show the individual parts of the transportation package starting from the outer cardboard box in the order of the unpacking steps. Note that the Hexapod is shrink-wrapped in antistatic foil together with desiccant bags (not shown). Preserve these materials too and use them again whenever repacking the Hexapod.









2.2 Mounting

The Hexapod may be mounted in any orientation, but different load limits apply to loads not on the Z-axis, and to loads applied when the unit is switched off (see Technical Data table, p. 59). Be sure not to exceed the load limits while installing your application.

The screw set (# 000013094) which comes with the M-850K086 / M-850K109 can be used for mounting the Hexapod on a mounting surface.

When protection class IP64 is required, prepare the Hexapod mechanics as described on p. 13 before mounting.

2.3 Connection and Startup

CAUTION

Do not interchange the C030B0003 and C030B0004 line driver boxes when connecting the system. Strictly adhere to the connecting instructions given below and to the labeling of boxes and cables.

Incorrect connecting can cause damage to the equipment.



The splitter box which combines the three cables from the strut controllers A, B and C into a ribbon cable (order# K040B0068 with M-850K086, order# K040B0069 with M-850K109) comes already installed on the Hexapod base plate. Note that this box is not shown in the dimensional drawing on p. 64.

- 1 Connect Hexapod mechanics, driver boxes, splitter boxes and Hexapod controller using the cables supplied like shown in Fig. 1 for M-850K086 / in Fig. 2 for M-850K109. Make sure that
 - the 6-headed cable (F-206.033) has each connector plugged into the correspondingly numbered socket of the controller
 - the K040B0070 cables on the Hexapod mechanics connect strut controller A with splitter box socket A, strut controller B with socket B and strut controller C with socket C
 - the labeled side of the power cables (K060B0028 for M-850K086, K060B0027 for M-850K109) connects to the M850B0123 splitter box

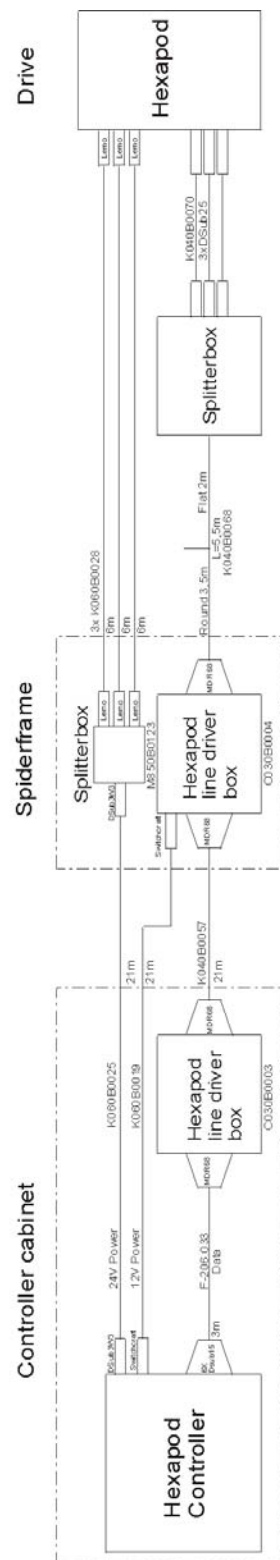


Fig. 1: System overview M-850K086

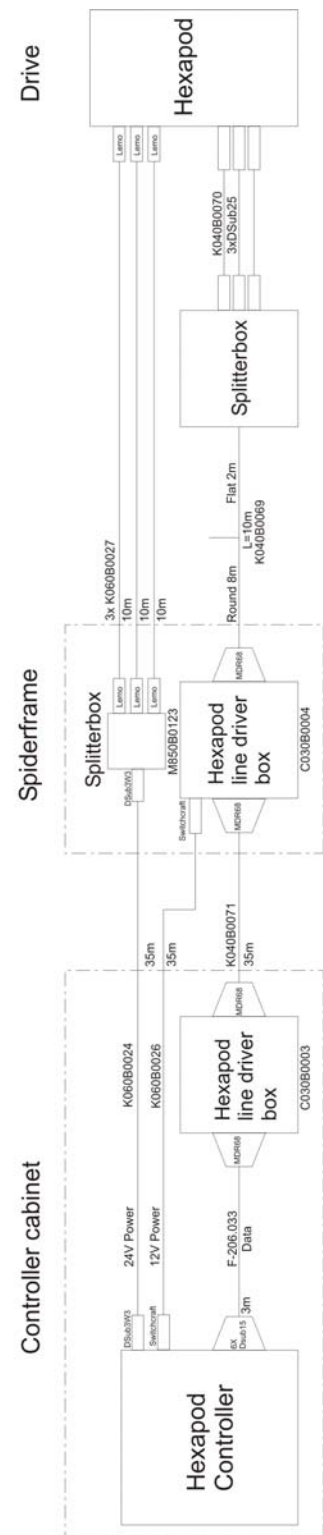



Fig. 2: System overview M-850K109

- 2 Verify that the mechanics is not at the end of a travel range or in contact with any object that might hinder movement.
- 3 Connect Hexapod controller to host PC.

NOTE

On the Hexapod controller side you will be using RS-232 port COM1. On the host PC side, either COM1 or COM2 can be used.

- 4 Power up host PC and Hexapod controller. See “Troubleshooting” p. 58 if you suspect that the controller is not booting properly.
- 5 Install the host software on the host PC:
The software package supports a common installation procedure. A setup program guides you through all installation steps using interactive dialogs. This program (setup,  icon) is located in the root directory of the M-840/M-850 software CD that comes with the system. After running the program, the M-840/M-850 host software is fully installed.
- 6 Start the Hexapod host software on the host PC. Make sure the software is set to use the port selected in step 3. Make sure the baud rate setting is the same at the controller and the host PC (the controller firmware defaults to 57.6 kBaud).
- 7 The first command entered in the command window must be “INI”. No other motion commands will be accepted until “INI” is executed.
- 8 If there are any problems with communication, please read the Troubleshooting section, p. 58.

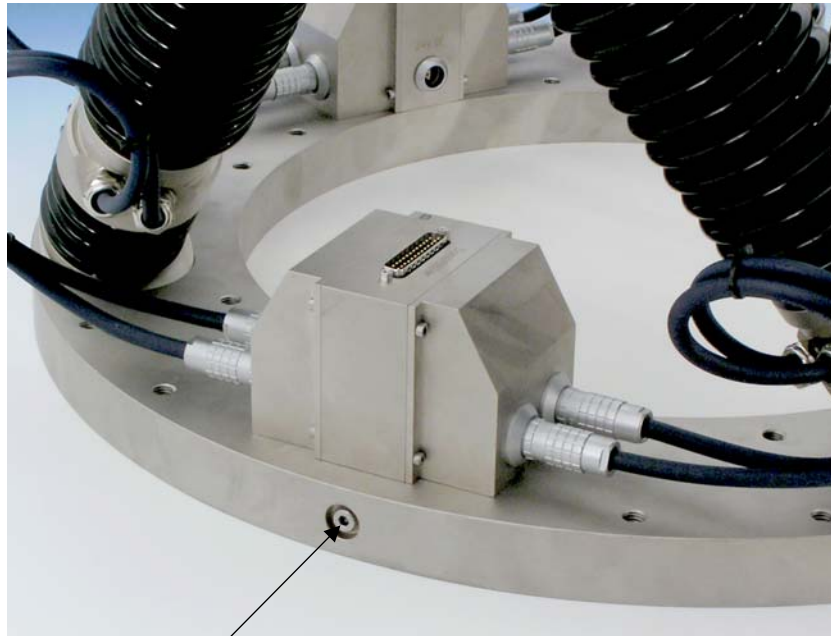
2.4 Protection Class IP 64

Protection class IP64 requires the following:

- The threaded plug (see Fig. 3) must remain in the air inlet (the Hexapod comes with the threaded plug inserted).
- The O-ring seals must be inserted in the appropriate slots on the bottom side of the Hexapod base plate.

The O-ring seals are not installed at delivery. For the slot locations see the dimensional drawing on p. 64. Use the inner and the outer slot, but not the center slot which is required for ventilation.

When protection class IP64 is not required, the O-ring seals and the threaded plug are not necessary.



Threaded plug

Fig. 3: Air inlet in the Hexapod base plate, shown with threaded plug inserted

3 System Description

M-850K086 / M-850K109 Hexapod systems consist of the Hexapod mechanics—a movable platform supported by six linear actuators—the control electronics, a few connecting cables and two line drivers (see p. 3 for a component list).

Motion in all six degrees of freedom can be accomplished using the DC-motor-driven linear actuators, which extend/contract the struts of the Hexapod platform.

The Hexapod is controlled by a PC-based 6-axis DC-motor controller (the Hexapod controller) with its two installed motion-control boards. The controller's operating software accepts motion commands via a serial (RS-232) communication link from a host PC (not included).

All positioning commands are given in Cartesian coordinates and transformed by the controller to the Hexapod actuator-axis-specific positions and velocities before execution.



Fig. 4: M-850K086 Hexapod mechanics

3.1 Hexapod Mechanics

The six variable-length, DC-motor-controlled linear-actuator “legs” (struts) steer the Hexapod platform to the commanded positions with micrometer accuracy.

The six linear actuators are mounted between the base plate and the platform. The advantages of the Hexapod design are low weight, compact structure, high stiffness, six-dimensional motion and high resolution.

3.1.1 Design

All components are designed as short as possible and are mounted free of backlash in axial orientation. This design gives the mechanical system exceptional stiffness and offers excellent positioning repeatability.

The joints at the strut ends are designed for extra-high stiffness in the radial direction. They are designed as functional modules, and can be manufactured, tested and replaced separately. The materials and lubricants used are chosen to assure long-term operation in the specified operational environment and temperature range.

The operation of the optical reference switch is not affected by rotation around the actuator axis: i.e. it works independent of the angular position of the strut-end joints and hence independent of the lengths of the other struts. Upon power-up of the Hexapod controller, an initialization routine must be first performed, during which each linear actuator is commanded to the absolute center of its travel range. All positioning commands are referenced to this center position.

Two limit switches are present to cut motor current and protect the unit from mechanical damage in case of a controller malfunction or software problems.

The Hexapod base plate contains all electrical connectors, cable grooves and the strut controllers.

All of the six linear actuators have a DC-motor-driven, backlash-free spindle, combined with a backlash-free gearhead. Each actuator can be controlled individually in length over the range of ± 5 mm (M-850K086) / ± 25 mm (M-850K109). Each set of lengths for the six linear actuators defines a one position (location and orientation) of the platform in six degrees of freedom. It is not possible to cause excessive mechanical stress by driving the struts to some random position.

3.1.2 Six-Axis Motion Synchronization

Even when the electronics drives the platform along orthogonal axes and around fixed pivot points, all six actuators have to be moved in harmony, based on complicated interpolations, to guide the platform along the defined trajectory.

All motion commands refer to a platform position defined by three linear and three rotational coordinate values. The axes about which rotations are defined (U, V, W) are initially coincident with XYZ. Their intersection, the pivot point, can, however, be shifted with a user command by any amount desired, and can lie inside or outside the system workspace. Moves which specify new X, Y or Z (translation) parameters also shift the pivot point (i.e. the pivot point “moves with” the platform). Similarly, a non-zero rotation around X (U-move) rotates the V and W rotation axes, and a non-zero rotation around Y (V parameter) rotates the W axis. This means, for example, that a W-move always rotates the platform about a line perpendicular to its plane.

To execute a move command, the system first evaluates the target position specification, then calculates how to get there from the current position in a smooth continuous vector motion, then performs that motion. See Hexapod Coordinate System, p. 23 for examples and illustrations.

3.2 Hexapod Controller

The Hexapod electronics consist of a PC-based controller. Software is provided to send ASCII commands to the controller from a (not included) host PC. In addition, the controller's ASCII command interface is fully described, so as enable use of custom software, if desired.

The Hexapod controller is connected to the mechanics as shown in Fig. 1 on p. 12.

Data transfer between the Hexapod controller and the host PC is based on an RS-232 data link with user-settable baud rate. This technique allows data transmission over large distances, if required.

For testing purposes, a keyboard and a VGA monitor can be connected to the controller and commands entered there directly. After starting the system, all activity, direct or via the host, will be displayed on the monitor connected to the controller.



Fig. 5: Hexapod controller connections

All operating commands to be performed by the controller can be sent via the communications interface. Some configuration changes must be made at the controller itself, either with a keyboard and monitor or via the controller diskette drive.

3.2.1 RS-232 Serial Interface

The RS-232 port data rate can be changed by changing the value in line 5 of the "hexbrate.dat" data file. The factory default setting is 57600 baud.

To edit the hexbrate.dat ASCII file in the controller file system, proceed as follows:

- 1 Connect a standard PC keyboard and VGA monitor.

- 2 Power up the Hexapod controller, and after it boots exit the Hexapod software; you will now have a DOS prompt.
- 3 Go to the "HEXAPOD" directory and, using the "EDIT" command (or, alternatively the DOS Commander, "DC"), access the HEXBRATE.DAT file. That file must have the following structure:

```
PHYSIK INSTRUMENTE (PI) GmbH  
street address  
postal code and city / Germany  
Baudrate  
57600
```

Other RS-232 parameters are as follows:

8 data bits,
1 stop bit,
no parity.

3.2.2 Communication Checks

If not already done so, install the software on the host PC as described in the "Quick Start" Section on p. 7.

Connect the controller and the host PC via RS-232 null-modem cable. Switch on the controller, start terminal program or the *M8X0Control* software on the host PC, select the communication port and type:

```
Help [RETURN]
```

The answer reports all commands that are currently available in your controller.

Next type in the Initialize command:

```
INI [RETURN]
```

Watch the system: it will move to the "INI" position. Even if the system is close to the "INI" position, a small movement of all struts can be observed.

Next type in the simplest move command

```
MOV Z1 [RETURN]
```

Watch the system. It will lift the platform up 1 mm.

3.2.3 Manual Control Pad

The Manual Control Pad (F-206.MC6) option is a useful addition for simplifying test and setup procedures. It consists of an interface board (C-855.60) that installs in the Hexapod controller and a control pad with six digital “potentiometer” knobs. The control pad allows manual control in all 6 degrees of freedom with a variable step size.

Firmware versions newer than hex0030.exe support this option.



Fig. 6: Six-axis manual position control pad and interface board for the Hexapod system

- 4 Verify that jumpers JP1 and JP2 on the C-855.60 manual pad control interface board are both open (base address 0340 hex).
- 5 Install the interface board in the Hexapod controller (see Section 3.2.4 below).
- 6 Connect the cable of the manual control pad to the newly installed control board.
- 7 Switch on the controller (firmware versions newer than hex0030.exe required). The manual pad should be recognized automatically.

The step size to use for each axis can be set using the SST command, (p. 44).

Troubleshooting: If the controller does not have a built-in display, connect a standard VGA monitor to it. Switch on the controller and observe the controller boot process on the monitor. The firmware detects the board automatically and a green colored “Manual control board available” message appears. If no such board is installed, a red colored message

reading “Manual control board not available” can be seen.

40.900000	7.000100	57.420000	57.420000
28800.000000	-7.000100	22.570000	63.580000
0.500000	7.000100	0.000000	0.000000
1.000000	-7.000100	0.000000	41.010000
2.000000	7.000100	50.000000	50.000000
10.000000	-7.000100	0.000000	0.000000
7.100000	6.000100	-42.580000	-42.580000
	-6.000100	47.430000	6.420000
	6.000100	0.000000	0.000000
	-6.000100	-42.580000	-42.580000
	6.000100	-47.430000	-6.420000
	-6.000100	0.000000	0.000000
		0.000000	41.010000
		-50.000000	-50.000000
		0.000000	0.000000
	0.000000	57.420000	57.420000
	0.000000	-22.570000	-63.580000
	0.000000	0.000000	0.000000

Manual Pad Controller Board AVAILABLE

Fig. 7: Firmware boot screen when manual pad controller board is installed

3.2.4 Installing Add-On Cards in the Hexapod Controller

A number of available options require installation of an associated add-on card in the Hexapod controller. To install such cards, follow the steps below:

- 1 Prior to opening the controller case, disconnect the power cable. Follow General Accident Prevention Rules!
- 2 Open the controller housing by removing the four Torx screws inside the handles at the back panel of the controller, using the Torx driver TX8 (#3683) that comes with the system.
- 3 Lift the cover slightly and disconnect the ground cable. Remove the cover.
- 4 Lift the lever to release the daughterboard retaining clamp. Remove the clamping plate.
- 5 Remove the screw and cover bracket from a free ISA slot.
- 6 Carefully insert the new card into a free ISA slot and fasten it with the screw.



CAUTION

Be gentle when inserting the card: use of excessive force can cause hairline cracks.

- 7 Replace the clamping plate and relatch using the lever.
- 8 Make sure that no internal header connectors have been dislodged.
- 9 Connect the ground cable to the controller cover, slide the cover carefully into position, then insert and tighten the screws.

4 Hexapod Coordinate System

All move commands and coordinate transformations are based on the following axis definitions:

- The Hexapod struts are mounted on the base plate at 6 joints, B1 to B6, arranged in a circle.
- The opposing three joint-pairs, A1 to A6, are connected to the platform located on a circle.
- The origin of the fixed coordinate system XYZ is located in the center of the upper six joints A1 - A6. It is considered the center of the Hexapod after initialization.

All translations (XYZ moves) are performed on an interpolated straight-line path. That means all struts start and stop their moves at the same time and their velocities are calculated accordingly.

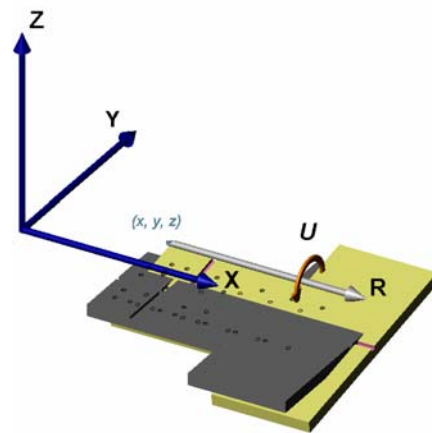
For pure translations, the orientation of the platform stays unchanged. For rotations, the current pivot point is taken into consideration. It can be defined with the linear coordinates R, S, T and stays relative to the platform. Any rotations (U, V and W moves) are referenced to the new pivot point.



The final position after a move with rotation components is calculated by considering the UVW position components in the order U then V then W. This is done without regard to whether these values were explicitly given in the current command or the result of previous commands.

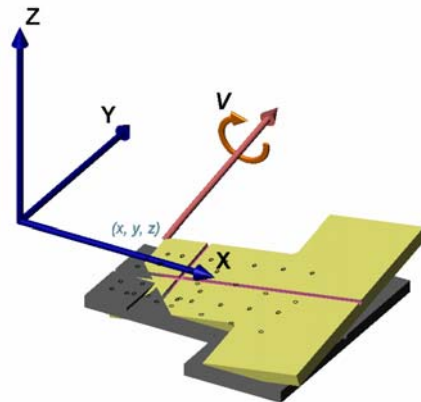
The evaluation of position specifications is illustrated below. To facilitate easy visualization, a T-shaped top-plate (as with F-206, for example) has been used in place of the round M-850K086 / M-850K109 platform.





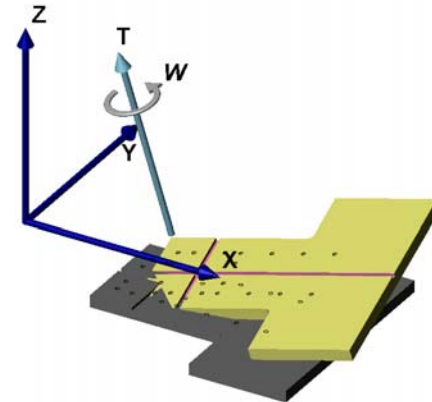
Top plate of the M-850K086 / M-850K109 is marked with the Hexapod coordinates



-  Platform at INI position (XYZ axes shown displaced to reduce clutter)
-  Platform at a position (x, y, z) and U=10



-  Platform at INI position
-  Platform position of (x, y, z), U=10 and V=-10





-  Platform at INI position
-  Platform position of (x, y, z), U=10, V=-10 and W=10

Fig. 8: Platform positions illustrated with F-206 top-plate. XYZ axes shown displaced to reduce clutter, pivot point set to "upper left" corner of platform.

5 System Commands

The Hexapod system comes with control software for running on a host PC (see the appropriate software manuals for details regarding the use of this software). Alternatively, you can employ custom software.

With the direct input facilities of the host software you can enter the system commands described in this section.

5.1 Command Structure

Lowercase and uppercase letters are allowed. The order of command parameters is not important.

All commands are transferred via the RS-232. For RS-232 communication, parameters are 57600 baud, no parity, 8 data bits, one stop bit. A standard null-modem cable is to be used to connect the host with the controller.

5.1.1 Command End of Line Terminator

All commands are transferred as strings with a `LF` (ASCII character decimal 10, hex 0A) as terminator. It may be possible to use a carriage return `CR` in addition to or instead of a line feed. The command line terminators are not usually shown explicitly in this manual.

5.1.2 Report Terminator

Report messages (responses) are also terminated by line feeds. If a report consists of more than one line, all lines but the last have a single space (`#32,#20h`) preceding the line feed. This fact can be used to determine whether the controller has more data to send. Response terminators are shown in this manual for some multi-line responses only.

5.2 Command Reference (alphabetical)

*IDN? (Get Identity Number)

Description: Reports the device identity number.

Format: *IDN?

Parameters: none

Response: One-line string terminated by line feed, e.g.
PHYSIK INSTRUMENTE
(PI),HEXAPOD,0,V5.1.3 - 061004

CST? (Get Stage name)

Description: Reports the name of the stage connected to the specified axes.

Format: CST? [X] [Y] [Z] [U] [V] [W] [A] [B]
X, Y, Z, U, V, W : linear and rotary axes of the Hexapod
A, B : separate axes
CST ? without any parameters corresponds exactly to CST? X Y Z U V W (if no separate axes are configured) or CST? X Y Z U V W A B (if separate axes are configured)

Examples: CST?
Response (with no separate axes configured):

```
X=HEXAPOD_AXIS_XSP LF
Y=HEXAPOD_AXIS_YSP LF
Z=HEXAPOD_AXIS_ZSP LF
U=HEXAPOD_AXIS_USP LF
V=HEXAPOD_AXIS_VSP LF
W=HEXAPOD_AXIS_W LF
```

```
X=HEXAPOD_AXIS_XSP LF
Y=HEXAPOD_AXIS_YSP LF
Z=HEXAPOD_AXIS_ZSP LF
U=HEXAPOD_AXIS_USP LF
```

```
V=HEXAPOD_AXIS_VSP LF
W=HEXAPOD_AXIS_WSP LF
A=M-505.6PDSP LF
B=M-505.6PD LF
```

CST? XA

Response (if no separate axes are configured):

```
X=HEXAPOD_AXIS_XSP LF
A=NOSTAGE LF
```

Response (if axis A is configured for M-505.6PD):

```
X=HEXAPOD_AXIS_XSP LF
A=M-505.6PD LF
```

ERR? (Get Error)

Description: Get Error code. Error codes almost always and in most circumstances refer to the previously received command (some innocuous commands like VER? do not always set the code to 0). Note that the ERR? command itself never fails and sets the error code to 0.

- | | |
|----|--|
| 0 | No error |
| 1 | Parameter syntax error |
| 2 | Unknown command |
| 5 | INI required before move at this time |
| 6 | SGA parameter out of range |
| 7 | Motion range exceeded. |
| 8 | Velocity range exceeded. |
| 9 | Attempt to set pivot point while U, V or W not all equal to 0 |
| 10 | Last command was "STOP"; INI required before next move or before valid position data can be obtained |
| 11 | SST parameter out of range |
| 13 | NAV parameter out of range |
| 15 | Invalid axis identifier |

- 17 Command parameter out of range
- 23 Invalid Axis
- 46 F-361 (Optical Power Meter) missing
- 47 F-361 cannot be initialized/is not initialized
- 48 F-361 communications error
- 53 MOV! command motion in progress
- 54 Unknown parameter
- 200 No stage configured
- 201 File with stage/axis parameters not found

Format: ERR?

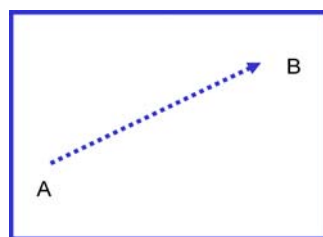
Parameters: none

Response: Error number

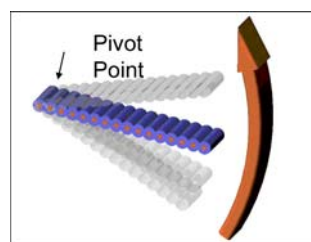
Trouble-shooting System is busy moving

FSN (Fast Scan)

Description: Fast scan. Executes a fast scan following a trajectory described by different parameters. The voltage at the analog input specified by the parameter [A] is read >500/s during motion.



FSN Y2.6 D0 C0 R0 L0.5 A2



FSN V0.6 D0 C0 R0 L0.5 A2

Fig. 9: Fast scan examples

CAUTION



Scan command runout may cause damage to the attached application.

The trajectory specified by the [X] [Y] [Z] [U] [V] and [W] parameters is not followed as exactly as motion initiated with a MOV command, but rather with a certain amount of wobble. For large scanning ranges, for example 1 mm, this may result in an additional deviation of up to 2.6 μm from the desired trajectory, which, if unexpected, could damage the attached setup.

Default: A: 1
 L: 1 [V]
 D: 1
 R: 0
 C: 0

xxFormat: FSN [X] [Y] [Z] [U] [V] [W] [L] [D] [R] [C] [A]

Parameters: [A] specifier indicating which Optical Board or which Optical Power Meter (F-361) analog input to use. Can be A1 or A2. If omitted, A1 is used.

If there is an F-361 Optical Power Meter (OPM) configuration file (C:\HEXAPOD\F-361.DAT), the OPM will be addressed and any optical boards present will not be accessible, otherwise the specified optical board will be addressed.

[L] Threshold Level. Level of analog input, in volts for an optical board analog input, or in the unit specified in the TAV command for an OPM.

[D] If D0 is specified, the scan direction will be inverted.



[R] If R1 is specified, the position after finishing the command will be the same as the position before. If R0 is specified, the Hexapod remains at its last scan



position.

[C] Describes whether the scan is performed symmetrically or not: C1=symmetry, C0 no symmetry.

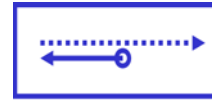


Fig. 10: FSN parameters

Examples:	FSN Y0.1	Let XS, YS, ZS, US, VS and WS be the position when FSN is invoked. The trajectory begins at XS, YS, ZS, US, VS, WS and stops at XS, YS+0.1, ZS, US, VS, WS.
	FSN X0.1 D0 R1	Since D0 (invert) is specified, this command corresponds exactly to the command FSN X-0.1 R1. Here, the resulting trajectory begins at XS, YS, ZS, US, VS, WS and stops at XS-0.1, YS, ZS, US, VS, WS. Having finished scanning, a move to the start position of XS, YS, ZS, US, VS, WS will be executed.
	FSN V0.1 C1	Preparing to scan, the Hexapod moves to the scan start position at XS, YS, ZS, US, VS-0.05, WS. The scan stops at XS, YS, ZS, US, VS+0.05, WS. The Hexapod remains at this position. See figure below.

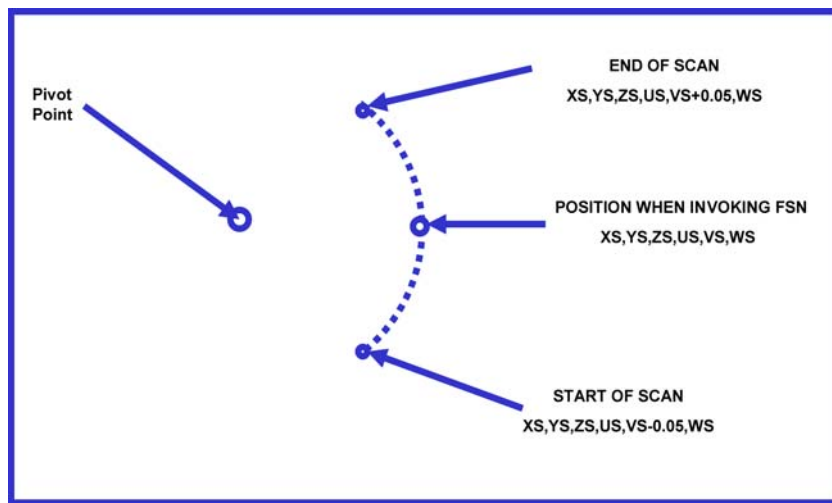


Fig. 11: Before and after FSN

Response: '1' The maximum voltage reached the threshold level.
'0' The maximum voltage did not reach the threshold level, or an error occurred. Since errors will also cause this response, the ERR? command should be issued to see what happened.

Troubleshooting: Parameter out of range.

Parameter Charts:

Start of Scan Position Table

Position before evoking FSN	Parameters of FSN	D0 C0	D0 C1	D1 C0	D1 C1
XS	X	XS	$XS+X/2$	XS	$XS-X/2$
YS	Y	YS	$YS+Y/2$	YS	$YS-Y/2$
ZS	Z	ZS	$ZS+Z/2$	ZS	$ZS-Z/2$
US	U	US	$US+U/2$	US	$US-U/2$
VS	V	VS	$VS+V/2$	VS	$VS-V/2$
WS	W	WS	$WS+W/2$	WS	$WS-W/2$

End of Scan Position Table

Position before evoking FSN	Parameters of FSN	D0 C0	D0 C1	D1 C0	D1 C1
XS	X	$XS-X$	$XS-X/2$	$XS+X$	$XS+X/2$
YS	Y	$YS-Y$	$YS-Y/2$	$YS+Y$	$YS+Y/2$
ZS	Z	$ZS-Z$	$ZS-Z/2$	$ZS+Z$	$ZS+Z/2$
US	U	$US-U$	$US-U/2$	$US+U$	$US+U/2$
VS	V	$VS-V$	$VS-V/2$	$VS+V$	$VS+V/2$
WS	W	$WS-W$	$WS-W/2$	$WS+W$	$WS+W/2$

FSN Finished Position Table

Position before evoking FSN	R0	R1
XS	End-of-Scan Position	XS
YS	End-of-Scan Position	YS
ZS	End-of-Scan Position	ZS
US	End-of-Scan Position	US
VS	End-of-Scan Position	VS
WS	End-of-Scan Position	WS

FSN? (Get Fast Scan Result)

Description: Get result of the FSN command. The system reports the position of the highest input voltage and its value.

Format: FSN?

Parameters: none.

Response: X=0.1001 SP LF SP = space
Y=1.002 SP LF LF = line feed
Z=-0.01 SP LF LW shows the analog
U=0.0 SP LF signal level at its
V=1.1 SP LF maximum. For an optical
W=0.1 SP LF board, the unit is volts; for
LW=3.99 LF an OPM the response will
 contain unit, as set with
 the TAV command. The
 position is given in
 absolute coordinates, i.e.
 not relative to the start
 position of the scan
 trajectory or the position
 when evoking FSN.

HELP

Description: Lists all available commands

Format: HELP

Parameters: none

Response: Command List

Troubleshooting: RS-232 communication breakdown
System is busy moving

INI (Initialize)

Format:	INI [A][B]
Parameters:	none for Hexapod. A for separate axis A, B for separate axis B
Response:	none
Troubleshooting:	DC power failure System is busy moving

In case INI is invoked without any parameters, the Hexapod goes to its reference point at a safe speed. The initialization is carried out in four steps:

- 1 All struts start toward their reference positions (midpoint reference switches) at the same time at the same velocity.
Note that the platform trajectory in X, Y, Z, U, V, W coordinates can be quite complicated.
- 2 The platform is then raised slightly so that the reference switches can all be re-approached from the same side.
- 3 The struts are then contracted one by one to the reference point.
- 4 The platform position is readjusted slightly, usually upwards. All motion parameters except the pivot point, velocity and manual pad step-size are reset.

To stop motion during an INI command, send an ASCII #24 to the controller (with the *M-840/M-850 Control* software on the host computer, this can be done by pressing the ESC key)

INI with A or B parameters will move separate axes to their reference positions. To initialize separate axes, INI must have been invoked without parameters before.

Each time INI is invoked without parameters, separate axis initializations must be performed again before those axes are used.

MAR! (Move and Respond)

Identical to the MOV command (see below), except that two separate one-line responses are given, one when the motion actually begins and one when the motion completes. (Some versions of the Control software may not recognize these responses as valid and instead display an error message even though the command executes properly).

MOV (Move Absolute)

Description:	<p>Move Hexapod or separate axis</p> <p>Units for X,Y,Z: mm, U,V,W: deg,</p> <p>Units for A, B depend on connected stage.</p> <p>The values are interpreted as floating point format.</p> <p>Note that the direction of the axis around which a V move is calculated depends on the U position; the W axis direction depends on both U and V positions. See Hexapod Coordinate System, p. 23 for details.</p> <p>Internal accuracy for all transformations is 18 digits.</p> <p>The controller checks if the programmed position and all positions of the trajectory are situated within the Hexapod's working space, before it starts motion. If only one of the six Hexapod coordinates is out of range, the motion of the Hexapod will not be started. It is sufficient to set new positions only for the axes to be moved.</p>
Format:	<p>MOV [Xp] [Yp] [Zp] [Up] [Vp] [Wp] [Ap] [Bp]</p> <p>X, Y, Z, U, V, W linear and rotary axes of the Hexapod; A, B separate axes</p> <p>p Parameter [mm] or [deg]</p>
Example:	<p>After initialization the system position is:</p> <p>X=0; Y=0; Z=0; U=0; V=0; W=0.</p> <p>The new command is:</p>

MOV Y1.245678 X1.23 V0.56789

The new target position is:

X= 1.23mm Y= 1.2457mm Z= 0mm;

U= 0deg V= 0.5679deg W= 0deg.

After a new command MOV Z1.2 the new target position is:

X= 1.23mm; Y= 1.2457mm; Z= 1.2mm;

U= 0deg; V= 0.5679deg; W= 0deg.

The pivot point is set by the SPI command. All rotation is done around axes through the pivot point. See Section 4, "Hexapod Coordinate System" for details

Response: none

Troubleshooting: Parameter out of limits

MOV?	(Motion Complete)
------	-------------------

Description:	Motion complete? The system reports '1'. Since commands are called one after another from the FIFO buffer, the system will not send '1' while a MOV command is running...
Format:	MOV?
Parameters:	none
Response:	'1', if motion complete.
Troubleshooting:	System is busy moving
Remarks:	MOV? is not suitable to be used within sequences of MOV! commands. If a MOV? is called while a MOV! command is running, the system will await standstill before sending '1'.

MOV! (Move To Absolute Position)

Description: This command is very similar to the MOV command. While performing a MOV! command movement, a new target position can be set by a subsequent MOV! command. In this case, new target positions will be programmed immediately. All motions will change in a smooth manner according to the acceleration limitations settings in the C842data.dat configurations file entry.

To avoid stops in movement between subsequent MOV! commands, MOV! commands should be sent periodically. The cycle time must be set using the SCT command.

The MOV! command will not refresh the real actual position that is displayed on the controller's monitor. No movement bar or any other feedback will be seen on the controller's monitor. Movements caused by the MOV! command cannot be stopped!

CAUTION

The trajectory is executed along a trajectory described by the parameters [X] [Y] [Z] [U] [V] [W]. The motion does not follow this trajectory exactly. There is a wobbly motion occurring instead. For large scanning trajectories, for example 1 mm, this may result in a deviation of > 2.5 µm from the desired trajectory which could damage the attached setup.



Moves Hexapod but NOT separate axis.

Units for X,Y,Z: mm, U,V,W: deg.

The values are interpreted as floating point format.

Sequence of rotation is U > V > W.

Internal accuracy for all transformations is 18 digits.

The controller checks if the programmed

position can be reached, before it starts motion. If only one of the six Hexapod coordinates is out of range, the motion of the Hexapod will not be started. It is sufficient to set new positions only for the axes to be moved.

Format:	<p>MOV! [Xp] [Yp] [Zp] [Up] [Vp] [Wp]</p> <p>X, Y, Z, U, V, W linear and rotary axes of the Hexapod.</p> <p>p Parameter [mm] or [deg]</p>
Example:	<p>After initialization the system position is:</p> <p>X=0; Y=0; Z=0; U=0; V=0; W=0.</p> <p>The new command is: RUN! Y1.245678 X1.23 V0.56789</p> <p>The new target position is:</p> <p>X= 1.23mm Y= 1.2457mm Z= 0mm;</p> <p>U= 0deg V= 0.5679deg W= 0deg.</p> <p>After a new command MOV! Z1.2 the new target position is:</p> <p>X= 1.23mm; Y= 1.2457mm; Z= 1.2mm;</p> <p>U= 0deg; V= 0.5679deg; W= 0deg.</p> <p>The pivot point is set by the SPI command. All rotation is done around a fixed XYZ coordinate system. Rotation does not affect the orientation of the coordinate system.</p>
Response:	none
Troubleshooting:	Parameter out of limits
Remarks:	<p>As long as a hexapod is in motion caused by a MOV! command, only the commands MOV!, STOP, POS? and TAV? will be performed immediately. Other commands will cause a delay until the MOV! target position is reached before executing.</p> <p>During MOV! motions the strut velocities are limited by the velocity that is set by the VEL command. Since the Hexapod's velocity has the same order of magnitude as the strut velocities, Hexapod's velocity can be limited.</p>

NAV (Set Number of Values for TAV?)

To use this command, an optical board (optional) must be installed.

Description:	Set number of readings of the analog signal to average in order to determine its level. Subsequent TAV? commands will reply with the average of the specified number of readings. Range: 1 to 10000. Default: N = 1, A1
Format:	NAV N [A]
Parameter:	N: Number of readings A: Optical board specifier, can be A1 or A2, if not specified, board 1 is read
Example:	NAV 10 A2 The next TAV? A2 command will reply with the average of 10 readings of the analog input of optical board 2.

NAV? (Get Number of Values for TAV?)

To use this command, an optical board (optional) must be installed.

Description:	Reports the programmed number of readings of the analog signal to be averaged when a value is required.
Format:	NAV? [A]
Parameter:	A: Optical board specifier, can be A1 or A2, if not specified, board 1 is read
Response:	N= 1 to 10000
Troubleshooting:	System is busy moving

POS? (Get Position)

Description:	Get Position of the Hexapod or the separate axes. No response during motion.
Format:	<p>POS? [X] [Y] [Z] [U] [V] [W] [A] [B]</p> <p>X, Y, Z, U, V, W linear and rotary axes of the Hexapod</p> <p>A, B separate axes</p> <p>POS ? without any parameters corresponds exactly to POS ? X Y Z U V W</p>
Examples:	<p>POS?</p> <p>Response : X=vvvvv<code>SP</code> <code>LF</code></p> <p> Y=vvvvv<code>SP</code> <code>LF</code></p> <p> Z=vvvvv<code>SP</code> <code>LF</code></p> <p> U=vvvvv<code>SP</code> <code>LF</code></p> <p> V=vvvvv<code>SP</code> <code>LF</code></p> <p> W=vvvvv <code>LF</code></p> <p>POS? A X</p> <p>Response : A=vvvvv<code>SP</code> <code>LF</code></p> <p> X=vvvvv<code>LF</code></p> <p>(<code>SP</code> space; <code>LF</code> line feed)</p>
Troubleshooting:	<p>Answer comes after motion complete.</p> <p>The system reports the target position. If a move is in progress, that move is first completed.</p> <p>POS? can be evoked while Hexapod is in motion caused by a MOV! command. In this case, POS? reports the target position and not the actual position.</p>

SCT (MOV! Command Configurations)

Description:	In case Hexapod movements are controlled in a closed loop, MOV! commands should be sent periodically in order to avoid stutter effects in motion. The cycle time of must set by the SCT command.
Format:	SCT [Tp] p is the cycle time [ms]
Example:	SCT T29
Default:	T=0
Response:	none
Troubleshooting:	Parameter out of limits, ($t < 0$) or ($t > 10000$).
Remarks:	<p>Using the MOV! Command, the Hexapod will reach the target position at the end of the given cycle time by changing velocity settings for each strut according to the target position distance. It is recommended to set a cycle time (using the SCT command) exceeding the real average cycle time in order to prevent any stutter effects caused by time period jitter.</p> <p>Set the cycle time to 0 s if no cycle time dependant velocity changes are desired. As a consequence of this, the Hexapod struts will move with a velocity that is limited by the VEL command only. As a consequence of this, the target position might be reached before the cycle time has ended.</p> <p>Though an appropriate velocity is calculated for each MOV! command, the real Hexapod velocity cannot fall below a minimum value and the strut velocities will not exceed the velocity set by the VEL command.</p>

SCT? (Get MOV! Command Configurations)

Description: Get cycle time of the MOV! movement.

Format: SCT?

Response: Response : T=vvvvvSP LF

SGA (Set gain)

To use this command, an optical board (optional) must be installed.

Description: Set gain of the optical amplifier

Format: SGA N [A]

Parameters: N: Gain value, can be 1, 10, 100 or 1000
A: Optical board specifier (optional), can be A1 or A2, if not specified, board 1 is read
Default: N = 100, A1

Example: SGA 10 A2
Sets the gain of optical board 2 to a value of 10.

Response: None

Troubleshooting: System is busy moving

SGA? (Get Gain Value)

To use this command, an optical board (optional) must be installed.

Description: Get optical gain value. Reports the gain setting of the optical amplifier

Format: SGA? [A]

Parameters: A: Optical board specifier, can be A1 or A2, if not specified, board 1 is read

Response: A= 1 or 10 or 100 or 1000

Troubleshooting: System is busy moving

SPI (Set Pivot Point)

Description: Set Pivot Point (with R, S, T in mm)
This command is only executed, if angular positions are U=V=W=0.

Format: SPI [Rp] [Sp] [Tp] or
SPI [Xp] [Yp] [Zp]

Troubleshooting: Platform tilted (U, V or W not all 0)

All parameters (p) are given in mm. The command will only be executed if the platform is not tilted: i.e. U=V=W=0.

After initialization, the pivot point is set to RST (0,0,0). On the Hexapod, this point is located at the center of the lower surface of the top plate. The center of the mounting surface is located at XYZ (0,0,16).

Note: R, S and T are alias names for X,Y,Z axes.

Example: SPI R0.3 S22 T12
(same as SPI X0.3 Y22 Z12) will set the pivot point to the position X=0.3 Y=22 Z=12.

SPI? (Get Pivot Point)

Description: Get Pivot Point Reports coordinates of pivot point as R, S and T or X, Y and Z.

Format: SPI? [XYZ]

Response to SPI?: R= vvvvv`SP` `LF`
S= vvvvv`SP` `LF`
T= vvvvvLF (`SP` space; `LF` line feed)

Response to SPI? X= vvvvv`SP``LF`
 XYZ: Y= vvvvv`SP``LF`
 Z= vvvvv`LF` (`SP` space; `LF` line feed)

Note: R, S and T are alias names for X,Y,Z axes.

Troubleshooting: System is busy moving

SST (Set Step Size)

Description: Set step size for manual position control pad.
 Units for X,Y,Z: mm, U,V,W: deg.
 The values are interpreted as floating point format.
 It is sufficient to set new values only for the axes to be changed.
 Range: X, Y, Z: 0.0001 – 0.5 mm;
 U, V, W: 0.0001 – 0.5 deg

Format: SST [Xp] [Yp] [Zp] [Up] [Vp] [Wp]
 X, Y, Z, U, V, W linear and rotary axes
 p Parameter [mm] or [deg]
 defaults are all 0.01

Example: SST Y0.002 U0.05
 Sets the step size for axis Y to 2 µm and for U to 50 mdeg.


Response: none

Troubleshooting: Parameter out of limits

SST? Get Step Size

Description:	Get step size setting being used for manual position control pad
Format:	SST?
Response:	X= vvvvv <code>SP</code> <code>LF</code> Y= vvvvv <code>SP</code> <code>LF</code> Z= vvvvv <code>SP</code> <code>LF</code> U= vvvvv <code>SP</code> <code>LF</code> V= vvvvv <code>SP</code> <code>LF</code> W= vvvvv <code>LF</code> <code>SP</code> space <code>LF</code> line feed
Troubleshooting:	Parameter out of limits

STOP (Stop Motion)

Description:	<p>This command aborts the current move of the Hexapod platform. Because of timing constraints with a move in progress, this command may not be recognized at typing speed.</p> <p>With the Control software the blue STOP button  now sends #24 instead of STOP+LF. If motion is actually stopped, the error code will be set to 10 and an INI move will be required before POS? gives reliable values and other motion commands are allowed.</p> <p>To stop all motion (including motion of separate axes) #24 has to be sent.</p> <p>Motion initiated by the FSN command can only be stopped with the #27 (ESC) command (see below).</p> <p>Motion initiated by the MOV command can be stopped by pressing Ctrl -X on</p>
--------------	---

the controller keyboard.

Format: STOP

Parameters: none

Troubleshooting: Communication breakdown

SVO (Set Servo on or off)



CAUTION

Note that with the servo-control loop OFF, the Hexapod position is fixed by friction only. As a consequence of this, load capacity may sink dramatically. Hexapods can get damaged and sink down in this case.

Description: Set servo-loop of the Hexapod ON or OFF.

Note that with the servo-control loop OFF, no positioning of the Hexapod or axes A and B is possible.

The SVO command always affects both the Hexapod and the separate axes A and B.

To move the Hexapod again, the servo loop must be turned on again. The INI command automatically turns servo on.

Format: SVO N

Or

SVO [XN] [YN] [ZN] [UN] [VN]
[WN] [KN] [LM] [MN] [AN]
[BN]

Parameters: N = 0 for servo off

N = 1 for servo on

Example SVO 1

Turns the servo-loop on.

SVO U0

Turns the servo-loop off

Response: none

Troubleshooting: Wrong parameter

Note: The servo-loop setting affects both Hexapod and separate motor and piezo axes. Therefore, the following commands are identical:

SVO1

SVO X1

SVO A1

SVO M1

SVO? (Get Servo State)

Description: Reports the servo state of the Hexapod and axes A and B

Format: SVO?
[X][Y][Z][U][V][W][K][L][M][A][B]

Response: if evoked without any parameters:

0 for servo is off

1 for servo is on

Example: SVO? XYUAB
Response (in case servo is on):

X= 1 SP LF

Y= 1 SP LF

U= 1 SP LF

A= 1 SP LF

B= 1 LF

SP space

LF line feed

Note: axes X, Y, Z, U, V, W, A, and B always have the same servo state.

Troubleshooting: System is moving

TAV (Settings for Tell Analog Value)

This command addresses F-361 Optical Power Meters (OPM) only and can not be used to address optical boards.

To use this command, a F-361 configuration file with an entry for the specified OPM must be present in the C:\Hexapod directory of the controller, and an F-361 must be properly connected and switched on. See the F-361 User Manual for details.

Description:	Sets measuring unit and measuring range for an F-361 OPM.
Format:	TAV [A] [UuW/UmW/UdBm] [R0/R1]
Parameters:	<p>A: Optical Power Meter specifier, can be A1 or A2, if not specified, OPM 1 will be addressed.</p> <p>U (Unit) where Unit = uW, dBm or mW</p> <p>UuW: Sets the measuring unit to μW (1E-6 watt)</p> <p>UmW: Sets the measuring unit to mW (1E-3 watt)</p> <p>UdBm: Sets the measuring unit to dBm ([dBm] = $10 \log_{10} (\text{Power} / 1\text{mW})$)</p> <p>R (Sensitivity) where Sensitivity = 0 or 1</p> <p>R0: Achieves high accuracy with low signals, should be selected if the signal power is extremely low</p> <p>R1: Should be selected to enlarge the measurement range in order to measure higher power signals.</p>

Default values:	The default value of R (Sensitivity) is set by the corresponding entry in the "F-361.dat" configuration file, which is located in the \HEXAPOD directory of the controller. The factory default value for U is mW.
Background:	The F-361 has 9 power ranges and switches from one to another automatically when necessary. The highest range and the lowest range, however, cannot both be made available at the same time. R0 enables measuring in the lowest power range and disables measuring in the highest power range. R1 enables measuring in the highest power range and disables measuring in the lowest power range.

TAV? (Tell Analog Value)

Description:	<p>Tell analog value.</p> <p>Reports the level of the analog signal at the specified device in floating point with 12-bit resolution.</p> <p>With an OPM the value reported will include the units of measure, which can be specified in a TAV command. Value of 10000 indicates invalid reading.</p> <p>With an optical board, value is in volts (unit not included in response), in a 0-10 V range.</p>
Format:	TAV? [A] [U] [R]
Parameter:	<p>A: Device number (up to 2 optical boards or 2 optical power meters can be connected, but not one of each) can be A1 or A2, if not specified, device 1 is addressed</p> <p>U (Unit, OPM only)</p> <p>R (Sensitivity, OPM only)</p>
Response:	If TAV? is invoked with an U parameter, no analog value will be returned, but the

measuring unit will be returned instead:

U = uW or U=dBm or U=mW.

UuW: measuring unit is μ W (1E-6 Watt)

UmW: measuring unit is mW (1E-3 Watt)

UdBm: measuring unit is dBm

([dBm] = $10 \log_{10} (\text{Power} / 1\text{mW})$)

If TAV? is invoked with a R parameter, no analog value will be returned but the measuring range will be shown instead, R=0 or R=1.

Troubleshooting: Attempt to address device A1 when device A2 is desired or vice versa.

With F-361 OPM:

F-361 device is not powered up.

Connect the power supply and turn on the F-361 device by pressing the power on button. Since this button is also used to access configuration menus, it is labeled "menu enter."

Inconsistent baud rate settings at F-361 and in the F-361.DAT configuration file.

F-361 connected to / configured for incorrect serial port.

With optical board:

F-361.DAT file exists in controller C:\HEXAPOD directory, thus deactivating access to any optical boards. Rename this file.

VEL Set Velocity

Description: Set Velocity
The allowed range is 0.004 - 1.2 mm/s.
The velocity setting is the speed to which the platform will be accelerated during subsequent moves. If the move includes a rotary component, the speed set is that of the upper joint which must execute the largest displacement. (This definition ensures that the maximum

	<p>expansion/contraction velocity of any strut is not exceeded, as no joint can move faster than its strut expands/contracts!). Note that a different velocity is used for the platform motion in response to an INI command.</p> <p>The allowable velocity settings for A and B depends on stages configured.</p>
Format:	<p>VEL [Xv][Yv][Zv][Uv][Vv][Wv][Av][Bv]</p> <p>X,Y,Z,U,V,W linear and rotary axes of the Hexapod;</p> <p>A,B separate axes;</p> <p>v velocity setting [mm/s] or, for axes A or B, units as defined for stage</p>
Alternative Format:	VEL v
Parameters:	<p>Without any axis descriptor for Hexapod; use of any of the parameters X,Y,Z,U,V,V,W will set Hexapod velocity</p> <p>v: velocity value, for Hexapod in mm/s, for A B depending on stage parameters, mm/s or degrees/s.</p>
Example:	<p>VEL 1 sets the velocity of the Hexapod to 1 mm/s.</p> <p>VEL X3 sets the velocity of the Hexapod to 3 mm/s</p> <p>VEL W3 sets the velocity of the Hexapod to 3 mm/s</p> <p>VEL A0.02 sets the velocity of the separate axis A to 0.02 mm/s (or deg/s).</p> <p>VEL X3 U3 sets the velocity of the Hexapod to 3 mm/s</p> <p>VEL X1 U3 will cause an error message since velocity settings are inconsistent</p>
Response:	None
Troubleshooting:	<p>Parameter out of limits</p> <p>Specified separate axis not configured, or F-206.AC8 software option not installed</p>

Specified separate axis unit-size
parameter incorrect

Note: Even though Hexapod axis designators can be specified, the Hexapod velocity as a whole is set, not the speeds in the specific directions.

VEL? Get Velocity

Description: Reports the current velocity setting (rounded to 3 digits).

Hexapod: [mm/s]

Axis: [mm/s] or [deg/s],
depending on stage
parameter data.

Format: VEL? [X][Y][Z][U][V][W][A][B]
X,Y,Z,U,V,W for Hexapod, A for separate
axis A, B for separate axis B

Example: VEL? XUA

Response: X=vvvvv SP LF

U=vvvvv SP LF

A=vvvvv LF

VEL?

Response: vvvvv LF

Note: Even though Hexapod axis designators can be specified and reported, the Hexapod velocity setting as a whole is given, not the speeds of the specific directions. The A and B velocities do, however, refer to the individual separate axes.

Parameter: Optional for Hexapod, A for separate axis A, B for separate axis B

Response: Value if the velocity setting currently in effect.

Troubleshooting: System is busy moving

VER? Get Version

Description:	Get firmware version The system reports the firmware version of the controller.
Format:	VER?
Parameters:	none
Response:	Firmware version
Troubleshooting:	System is busy moving

VMO Virtual Move

Description:	Virtual Move The system reports whether or not the target position is reachable from the current Hexapod position. The command can be used to check the working space. To do so, move the Hexapod to the INI position before evoking VMO. No motion occurs. The current target position is not changed.
Format:	VMO [Xp] [Yp] [Zp] [Up] [Vp] [Wp] Identical to MOV command, except that no motion occurs
Parameters:	Axis parameters
Response:	0 indicates target position can be reached 1 indicates target position is outside the working space
Troubleshooting:	Answer comes after any current move completes

(#5) Query Motion Status

Description:	Polls the motion status immediately.
Format:	#5 (ASCII character 5)
Parameters:	none
Response:	0: motion complete, system ready for new command. 1: Platform is moving 2: Separate axis A is moving 4: Separate axis B is moving 6: Separate axes A and B are moving

(#6) Position Change?

Description:	Asks if position has changed since last POS? query.
Format:	#6 (ASCII character 6)
Parameters:	none
Response:	1 Position has changed 0 No position change.

NOTE

The *M-840/M-850 Control* program for the host PC does not support this Command.

(#24) STOP Motion


Description:	Similar to STOP command. Stops motion of axes A and B also. Motion caused by the MOV command can be stopped by pressing Ctrl X on the controller keyboard. Motion initiated by the FSN command can
--------------	--

	only be stopped with the #27 (ESC) command (see below).
Format:	#24 (ASCII character 24)
Parameters:	none
Response:	none
Remarks	If motion is actually stopped, sets error code to 10. After #24 or STOP, an INI move is required before POS? gives reliable values and other move commands are allowable.

(#27) (ESC)	System Abort
-------------	--------------

Description:	<p>System abort</p> <p>ASCII character #27 aborts the system.</p> <p>It can be used as an EMERGENCY STOP.</p> <p>Motion of the platform stops immediately, all servo registers are reset, the servo-loop is disabled. The controller emits a continuous beep at 300 Hz. For restart, the controller must be manually reset or turned off (power switch).</p>
Format:	#27 (ASCII-character 27)
Parameters:	none
Response:	none

NOTE

To get the *M-840/M-850 Control* program on the host PC to send an ESC character, press the red STOP button . Pressing the ESC key will not send an ESC over the interface. See also the STOP and #24 commands.

6 Operating Examples

The following two examples show how to communicate with the Hexapod system using PASCAL. In both cases, a line scan with 10 steps is performed.

Version #1 waiting for movement ready answer

```

procedure y_scan_m;
const  check_str: string[2] = '1'+#10; { "1" + linefeed
var    ch:          char;
        i:          integer;
        pos:        double;
        str_pos:    string;
        temp_str:   string;

begin

    pos:=0;                { set position to zero      }
    for i:=1 to 10 do      { 10 steps, loop        }
    begin

        pos:=pos+0.1;      { increment position    }
        str(pos:1:4,str_pos); { make a string        }
        set_output('MOV   { send CMD to the          }
Y'+str_pos);              controller                }
        set_output('MOV?'); { request for move      }
        temp_str:='';      complete
        repeat              { loop, waiting for "1"
            if readinputbuf(ch) then
                temp_str:=temp_str+ch;

            until (temp_str=    { until move complete    }
check_str);

        end;
        set_output('MOV X0 Y0 Z0 U0 V0 W0');

    end;
end;

```

Version #2 polling until movement ready

```

procedure y_scan_5;
const  check_str: string[2] = '0'+#10; { "0" + Linefeed }

var    ch:          char;
        i:          integer;
        pos:        double;
        str_pos:    string;
        temp_str:   string;

begin

    pos:=0;                { set position to zero      }
    for i:=1 to 10 do      { 10 steps, loop        }
    begin

        pos:=pos+0.1;      { increment the position  }
        str(pos:1:4,str_pos); { make a string          }
        set_output('MOV    { send CMD to the          }
        Y'+str_pos);      { controller            }
        repeat            { loop until move complete
        until (temp_str=
        check_str);        { until move complete

        temp_str:='';
        ch:=' ';
        sendcharrs232(#5); { send an ascii 5        }
        repeat            { loop for RS232 until LF    }
        until (ch=#10;     { until linefeed (LF)    }
        until (temp_str=   { comes                    }
        check_str);        { until move complete

    end;
    set_output('MOV X0 Y0 Z0 U0 V0 W0');

end;

```

7 Troubleshooting

No Communication via RS-232:

Check the configuration of the COM: port.
Is it set to 57.6 k baud, 8 data bits, 1 stop bit, no parity
on both sides?

Connect a keyboard and a monitor to the Hexapod
controller and watch the boot procedure. During the
firmware startup process, the communication settings
appear on the screen. All commands sent via RS-232
can be seen in the firmware status line.

The data file hexbrate.dat, which is located in the
C:\Hexapod directory, must have the following content:

PHYSIK INSTRUMENTE (PI) GmbH
street address
postal code city / Germany
Baudrate
57600

and must not contain a line with "GPIB4".

Is the right cable being used? Use a null-modem cable.

If no communication can be established, interface settings on
the host PC should be checked (Try disabling the
infrared port, if any, and make sure the serial port is
enabled).

8 System Specifications

8.1 Technical Data

Models	M-850K086	M-850K109	Units
Travel X *	±8	±39	mm
Travel Y *	±8	±44	mm
Travel Z *	±5	±25	mm
Travel U, V *	±1.4	±7	°
Travel W	±1.8	±9	°
Actuator stroke (L _s)	±5	±25	mm
Actuator design resolution	0.0025	0.0025	μm
Min. Incremental Motion X, Y	10	10	μm**
Min. Incremental Motion Z	1	1	μm
Min. Incremental Motion U, V, W	10	10	μrad
Repeatability X, Y	±2	±2	μm
Repeatability Z	±1	±1	μm
Repeatability U, V, W	±10	±10	μrad
Velocity X, Y, Z (typ.)	0.1	0.1	mm/s
Velocity U, V, W (typ.)	1	1	mrad/s
Velocity X, Y, Z (max.)	0.5	0.5	mm/s
Velocity U, V, W (max.)	5	5	mrad/s
Actuator Stiffness	>15	>15	N / μm
Load capacity, horizontal mount (Z-direction)	2000	2000	N
Load capacity, all orientations (CoG x,y = 0)	1100	1100	N
Self locking (load capacity when powered down or servo off), horizontal mount, Z-direction	2000	2000	N
Self locking, horizontal mount, V-tilt ±15°, CoG x,y = 0, Z < 75 mm	1100	1100	N
Self locking, horizontal mount, V-tilt ±40°, CoG x,y = 0, Z < 75 mm	600	600	N
Operating temp. Range	-20 to +30	-20 to +30	°C
Weight	35	35	kg

* The travel ranges of the individual coordinates (X, Y, Z, U, V, W) are interdependent. The data in this table show maximum travel (where at least one strut is totally extended). If motion from a particular starting point or in more than one axis is desired, the available travel may be less.

** (6-axis move)

8.2 Connectors and Pinouts

8.2.1 Hexapod Mechanics

The following sockets are located on the three strut controller boxes which are mounted on the Hexapod mechanics base plate:

- Motor Control Lines (DB25 connectors)

The splitter box which combines the three motor control lines from the strut controllers A, B and C into a ribbon cable (order K040B0068 with M-850K086, K040B0069 with M-850K109) comes already installed on the Hexapod base plate. Note that this box is not shown in the dimensional drawing on p. 64.

- Power Connectors (LEMO 2-pol.)

Motor power for all 6 Hexapod motors (24 V DC) is provided from the Hexapod controller via the M850B0123 splitter box.

8.2.2 Controller

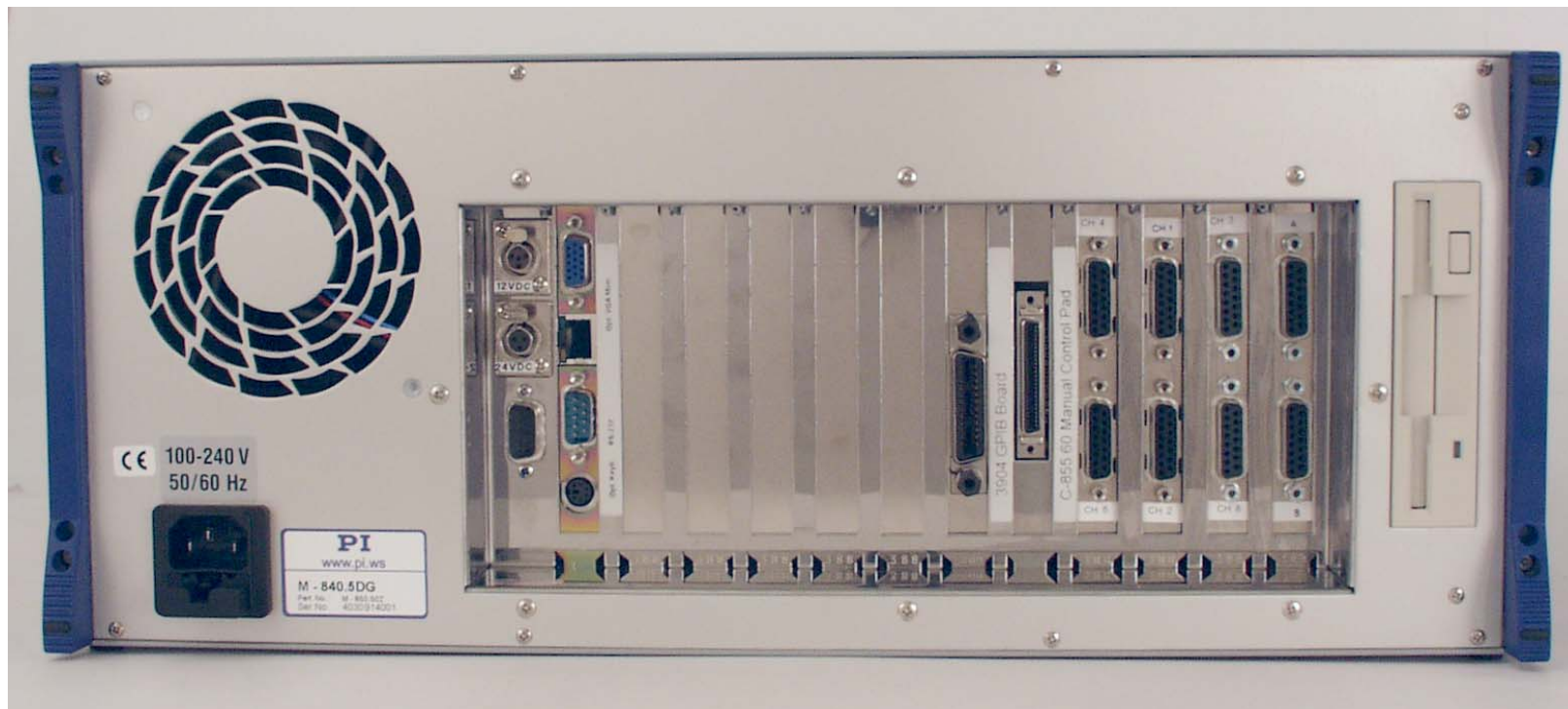


Fig. 12: Controller rear-panel connections and diskette drive

Connectors from top to bottom, left to right:

- Line power and fuse carrier:



Fig. 13: Push tab down and pull out carrier to access fuses

- Power sockets for Hexapod mechanics

4-pin socket (12 V, used to supply the C030B0004 Hexapod line driver box):

Pins	Function
1	GND
2	+12 V
3 & 4	unused

3-pin socket (24 V, used to supply the Hexapod mechanics):

Pins	Function
1	GND
2	+24 V
3	unused

- DB0 (unused)

- Connection for optional external VGA monitor, standard pinout
- Unused
- RS-232 (DB-9m) COM1 for connection to host PC, standard pinout.
- Connection for optional external keyboard, standard AT-type keyboard pinout
- Optional GPIB (IEEE 488) interface connection (not used with M-850K086 and M-850K109)
- Connection for manual control pad
- Eight motor-control connectors, one for each strut and two for optional axes A and B. Pinout is as follows:

Pins	Function
1	+ 12 V
9	Motor (-)
2	Motor (+)
10	Power GND
3	MAGN
11	SIGN
4	output +5 V
12	negative limit
5	positive limit
13	REFS
6	Limit GND
14	Encoder: A(+) / ENCA
7	Encoder: A(-)
15	Encoder: B (+) / ENCB
8	Encoder: B (-)

8.3.2 Hexapod Controller

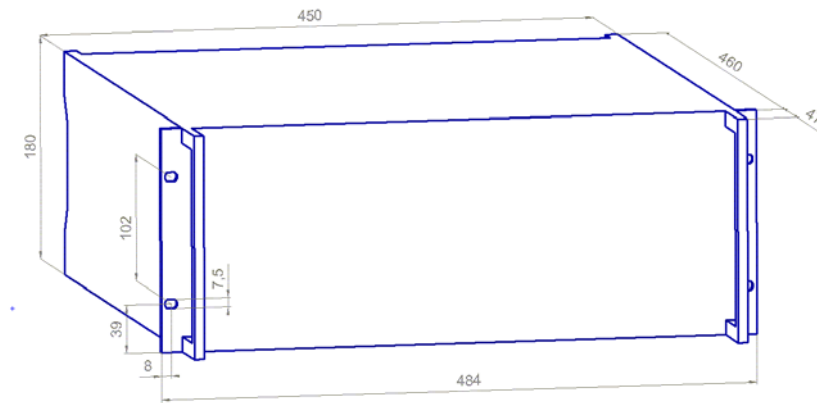


Fig. 15: Hexapod controller dimensions

8.3.3 Hexapod Line Driver Boxes

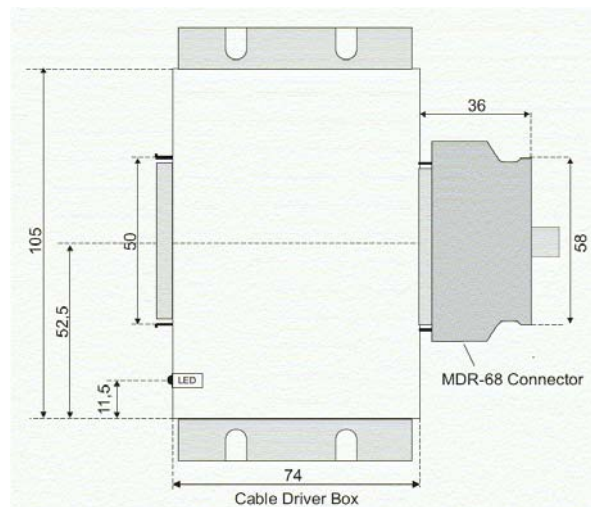


Fig. 16: Dimensions of C030B0003 and C030B0004 line driver boxes; C030B0004 has additional socket for Switchcraft power connector

